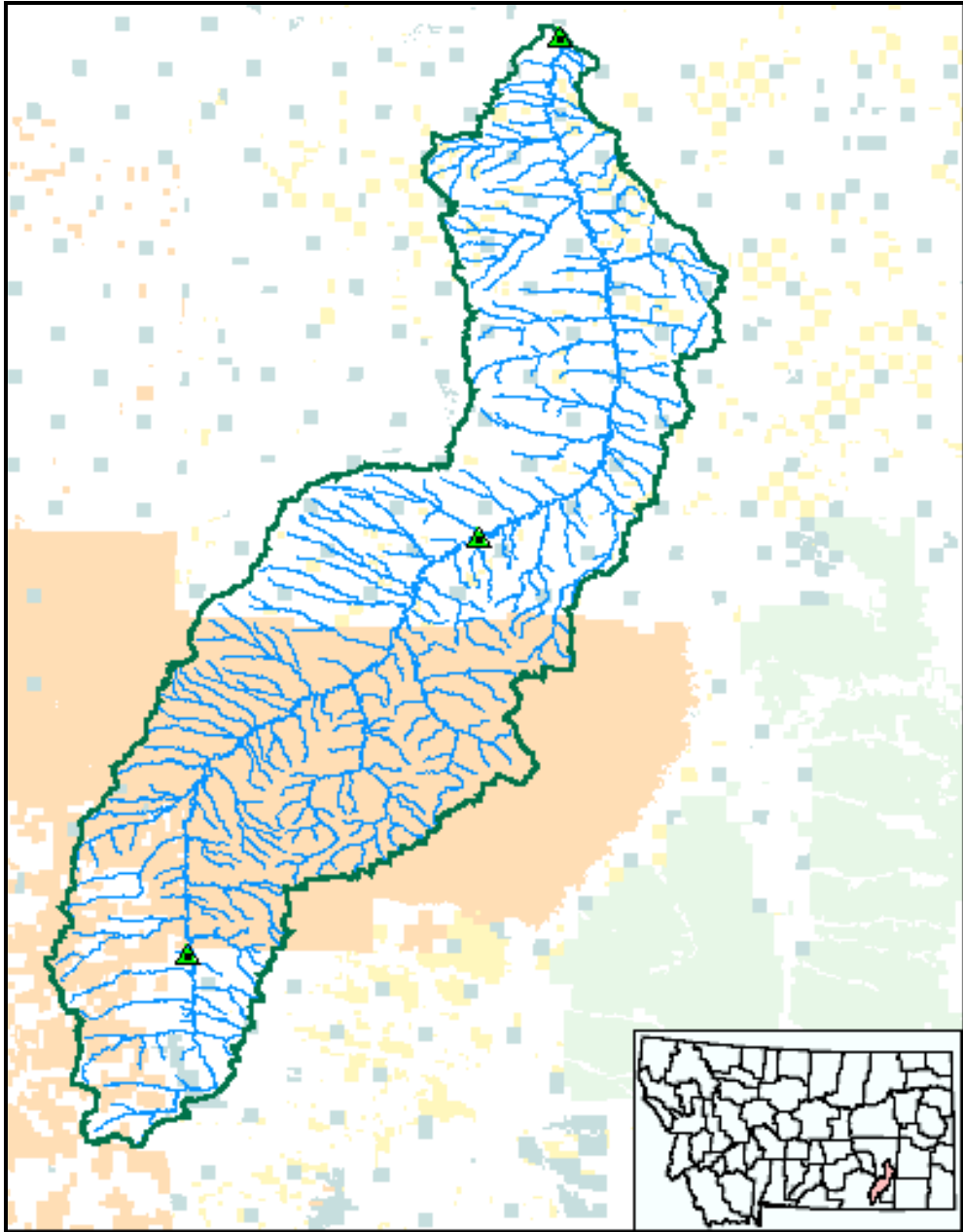


**Water Year 2007
Overview of Surface Water
Monitoring Data for SC, SAR and Flow
in the Rosebud Creek Watershed**



This cover map shows the locations of the three USGS stations which are the subject of this report.

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June, 2008**

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Introduction

When Coal Bed Natural Gas (CBNG) is developed, the methane must be allowed to desorb from the coal so that it can flow to production wells. This desorption is typically achieved by pumping groundwater (referred to as CBNG water) from the coal bed aquifer to reduce the hydrostatic pressure within the coal seam (allowing the methane to desorb) and create a pressure gradient within the aquifer. This pressure gradient causes methane to flow towards the pumping wells.

CBNG water in the Montana portion of the Powder River Structural Basin (PRB) is moderately saline, having a Specific Conductance (SC) on the order of 2,000 microSiemens per centimeter at 25 degrees Celsius ($\mu\text{S}/\text{cm}$). SC is the ability of water to conduct an electrical current at 25 degrees Celsius, and it is proportional to salinity (concentration of major ions, or salts). High salinity irrigation water may result in decreased crop yields, depending on the specific crop type and sensitivity to salts (See Fig. 1). The technical definition of Electrical Conductivity EC is “the ability of water to conduct a current”; however the Montana Department of Environmental Quality (MDEQ) regulations define EC as “the ability of water to conduct an electrical current at 25°C”. Since the EC definition is the same as the technical definition of SC, the SC values discussed in this report are directly comparable to the EC standards.

CBNG water in Montana typically is a sodium-bicarbonate (Na-HCO_3) type water, whereas Rosebud Creek has calcium and magnesium as predominant cations ($\text{Ca}\approx\text{Mg}>\text{Na}$). Because there is little sulfate in water from productive coal seams (VanVoast, 2003), bicarbonate is the predominant anion in both surface and ground water ($\text{HCO}_3>\text{SO}_4$). The dominance of sodium cations in CBNG water results in a high Sodium Adsorption Ratio (SAR; which is a complex ratio of Na to $\text{Ca}+\text{Mg}$); SAR in CBNG produced water typically ranges between 30 and 60 (ALL, 2001). Irrigation water with high SAR values may cause impacts to soil structure, and impair the ability for clay rich soils to infiltrate water (see Fig. 3). Within the PRB, some of the CBNG produced water is managed through treated or untreated discharge to surface waters under National Pollutant Discharge Elimination System (NPDES) permits, implemented under the Clean Water Act.

In Montana, NPDES permitting is conducted by the Montana Department of Environmental Quality (MDEQ) under the Montana Pollutant Discharge Elimination System (MPDES) permit program. If discharges were to occur on the Crow Reservation, NPDES permits would be needed from the EPA. If discharges were to occur on the Northern Cheyenne Reservation, NPDES permits would be needed from the Northern Cheyenne Tribe. There are currently (2008) no permits or proposals for CBNG discharge to Rosebud Creek, and no CBNG development is occurring in the Rosebud Creek Watershed.

In response to the potential for CBNG development in this area, the MDEQ and Northern Cheyenne Tribe have each developed surface water quality standards for EC and SAR in the Rosebud Creek watershed. These standards provide criteria against which to compare the monitoring data. These standards are summarized in Table 1 below. It should be

noted that the MDEQ standards have been reviewed and approved by the United States Environmental Protection Agency (EPA), and therefore have Clean Water Act standing. The Northern Cheyenne Tribe has been granted “Treatment as a State” (TAS) status by the EPA; however their standards have not been approved by the EPA. Thus, the Northern Cheyenne standards do not have Clean Water Act standing. Also, note that irrigation season standards are different from the non-irrigation season, and the MDEQ and Northern Cheyenne have defined the irrigation season differently. It should be noted that these values are used solely as a point of comparison; the comparisons in this report do not constitute regulatory determinations.

During Water Year 2007 the Montana Board of Environmental Review (BER) modified the standards which apply to CBNG in Montana. The most substantial change adopted by the BER was to designate EC and SAR “harmful” parameters. This change has not yet been approved by the EPA, and so is not in force at this time. If approved, this designation would require an “authorization to degrade” if a new or increased proposed discharge would cause an increase in the concentration of a harmful parameter which was already above 40% of the standard. Within the Rosebud Creek watershed, historical water quality values are rarely less than these 40% criteria.

Table 1: MDEQ and Northern Cheyenne Surface Water Standards Applicable for Water Year 2007 for EC and SAR in the Rosebud Creek Watershed

Irrigation Season ¹					
	MDEQ		Northern Cheyenne		
	Rosebud Creek	Tributaries	Southern Boundary	Northern Boundary	Tributaries
EC (uS/cm)					
Monthly Average	1000	500	1000	1500	1500
Not to Exceed	1500	500	2000	2000	2000
SAR					
Monthly Average	3.0	3.0	---	---	---
Not to Exceed	4.5	4.5	2.0	3.0	3.0

Non-Irrigation Season ¹					
	MDEQ		Northern Cheyenne		
	Rosebud Creek	Tributaries	Southern Boundary	Northern Boundary	Tributaries
EC (uS/cm)					
Monthly Average	1500	500	---	---	---
Not to Exceed	2500	500	2000	2000	2000
SAR					
Monthly Average	5.0	5.0	---	---	---
Not to Exceed	7.5	7.5	2.0	3.0	3.0

1: The irrigation season specified by the MDEQ is from March 1st to October 31st while the irrigation season specified by the Northern Cheyenne is from April 1st to November 15th.

The Interagency working group (IWG) for CBNG has identified regional surface water monitoring stations for the Rosebud Creek watershed. These stations, with their status for water year 2007 (10/1/06-9/30/07) relative to the IWG monitoring plan are listed on Table 2 below. Table 3 provides a summary of the IWG monitoring plan, further detail is available at <http://pubs.usgs.gov/fs/2005/3137/pdf/fs2005-3137.pdf>. Data currently or formerly collected at these stations included one or more of the following types: continuous flow, seasonal continuous specific conductance (SC), and periodic water-quality sampling. Water-quality sampling includes the measurement of flow, field parameters (SC, pH, temperature, etc) and the collection and analysis of water-quality samples. Although these samples were analyzed by the USGS for many parameters, this report will focus on SC and SAR, along with their relation to flow conditions. SC and SAR are considered to be the parameters most likely to be affected by CBNG development (MDEQ, 2003b), but SC and SAR in the natural system can fluctuate significantly with flow, which needs to be taken into account when evaluating possible CBNG effects on water quality. The monitoring at these stations was funded by the USGS, the BLM, and the Northern Cheyenne Tribe. An expanded set of analytical data are available from the USGS at <http://waterdata.usgs.gov/mt/nwis/>.

Table 2: Status of Surface Water Monitoring relative to the IWG Surface Water Monitoring Plan in the Rosebud Creek Watershed, Water Year 2007 (Conducted = ●; Partially Conducted = ⊙; Not Conducted = ○)							
Site	Continuous Stream-flow	Field measurements	Major Ions	Nutrients	Trace elements, primary	Trace elements, secondary	Suspended sediment
Rosebud Creek at reservation boundary, near Kirby	●	⊙	⊙	●	⊙	●	⊙
Rosebud Creek, near Colstrip	○	○	○	○	○	○	○
Rosebud Creek at mouth, near Rosebud	○	⊙	⊙	⊙	⊙	⊙	⊙

Table 3: IWG Recommended Surface Water Monitoring Plan

Constituent Class	Sampling Frequency
Streamflow	Continuous
Field Measurements	12 times per year
Major Ions	12 times per year
Suspended sediment	12 times per year
Primary Metals	12 times per year
Secondary Metals	2 times per year
Nutrients	2 times per year

Data Review

For all sites, please see the figures section for graphical display of the data. Tabulated summary statistics for the sites are provided on Table 4 below.

Table 4: Summary of USGS Monitoring Data in the Rosebud Creek Watershed for Water Year 2007

		Daily Mean		Water Quality Samples			Mean Monthly SC (uS/cm)
		Flow (cfs)	SC (uS/cm)	Flow (cfs)	SC (uS/cm)	SAR	
Rosebud Creek at Reservation Boundary near Kirby, MT	n	365	168	9	9	9	6
	min	0.7	605	2.0	816	0.4	759
	max	157	1010	33	1020	0.7	913
	mean	12.8	834	12	898	0.6	841
	median	4.1	848	7.4	902	0.6	838
Rosebud Creek near Colstrip, MT	n	---	---	---	---	---	---
	min	---	---	---	---	---	---
	max	---	---	---	---	---	---
	mean	---	---	---	---	---	---
	median	---	---	---	---	---	---
Rosebud Creek at mouth, near Rosebud, MT	n	---	---	1	1	1	---
	min	---	---	19	1790	2.8	---
	max	---	---	19	1790	2.8	---
	mean	---	---	19	1790	2.8	---
	median	---	---	19	1790	2.8	---

Indicates exceedance of MDEQ Irrigation Season Standards.

SC = Specific Conductance
uS/cm = microSiemens per centimeter

SAR = Sodium Adsorption Ratio

For each station where data are available, a summary of the daily mean flow and SC data from continuous monitors during water year 2007 is presented. Mean monthly SC values from the seasonal continuous monitor at Rosebud Creek near Kirby are compared to the mean monthly EC standards. No comparison is made to the mean monthly SAR standards since there are no months in which nine or more values of SAR were collected. Data for periodic water-quality samples (SC, SAR and flow) are also presented. Analytical results are compared to the MDEQ “not to exceed” (NTE) surface water standards for EC and SAR. Relations of SC vs. Flow, SAR vs. Flow, and SC vs. SAR based on historical data are presented in graphical form to allow evaluation of 2007 data in context.

Since SC and SAR are dependent on flow, it is important to recognize up front that flows during water year 2007 were higher than average for most of the year (223% of average at Kirby, which is the only station with continuous data). If comparisons are to be made

between water quality data from different seasons or years, it is important to take flow differences into account.

Rosebud Creek near Kirby

Flow and Specific Conductance were measured continuously at this site, with SC being seasonal (about April-October to match the irrigation season). Water-quality samples were also collected periodically. Mean daily flow values ranged from 0.7 to 157 cfs, with the mean being 12.8 cfs. These flows are 223% of historical (1979-2006) (see Fig. 3).

Daily mean SC data from the continuous monitor during the 6 months of seasonal record (April-September) in water year 2007 ranged from 605 to 1010 uS/cm. Monthly mean SC values ranged from 759 to 913 uS/cm. Analytical SC values from water-quality samples collected 9 times at this site ranged from 816 to 1020 uS/cm. Analytical SAR values from water-quality samples ranged from 0.4 to 0.7 (see Figs. 4-7).

SC and SAR values from either the continuous SC monitor or from analyses of water-quality samples did not exceed any MDEQ or Northern Cheyenne EC or SAR standards (see Fig. 4).

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2007 data along with historical data (see Figs. 5-7).

Rosebud Creek near Colstrip

No flow or analytical data were collected at this station during water year 2007.

Rosebud Creek near Rosebud

Flow and water quality sampling were discontinued at this site in water year 2007 due to lack of funding. However, one flow measurement and water-quality sample was collected in conjunction with an aquatic ecology sample. The one sample, collected on July 23, 2007, while the flow was 19 cfs, had an SC of 1790 uS/cm and an SAR of 2.8. This SC value exceeds the MDEQ's irrigation season NTE EC standard; the SAR value is less than the MDEQ's irrigation season NTE SAR standard. Mean monthly values were not calculated due to a lack of data.

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2006 data along with historical data (see Figs. 8-10).

Conclusions

During Water Year 2007 (October 2006-September 2007) flows within Rosebud Creek watershed were higher than historical averages. SC and SAR vary with flow so an evaluation of SC and SAR must also take flow into account.

A comparison of measured SC and SAR to the MDEQ surface water standards for EC and SAR showed that the only exceedance of a standard was for EC by one sample collected at Rosebud Creek near Rosebud. The fact that this exceedance occurred, even though it was a relatively wet year and no CBNG development has occurred in this watershed, indicates that elevated SC values can occur as a result of natural conditions.

A statistical trend analysis was not conducted for this data; however visual inspection of the SC vs. Flow, SAR vs. Flow, and SC vs. SAR graphs does not indicate noticeable deviation from historical trends. Since new stresses have not been applied to this watershed, deviations would not be expected.

References

- Ayers, R. S., and Westcot, D.W., 1985, Water Quality for Agriculture, FAO Irrigation and Drainage paper 29 (Rev 1), Food and Agriculture Organization of the United Nations.
- Hansen, B.R., Gratton, S. R., and Fulton A., 1999, Agricultural Salinity and Drainage, University of California Irrigation Program, University of California, Davis.
- MDEQ, 2003b, Record of Decision for the Montana Statewide Oil and Gas Environmental Impact Statement (http://www.deq.state.mt.us/coalbedmethane/pdf/RODAug7_03.pdf)
- VanVoast, W.A., 2003, Geochemical signature of formation waters associated with coalbed methane, AAPG Bulletin, v. 87, no. 4 (April 2003), pp. 667–676.

Reviewers

Mike Philbin

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Figures

Figure 1: Comparison of Crop Yield to SC (Salinity) and Recorded 2007 SC Values in the Rosebud Creek Watershed

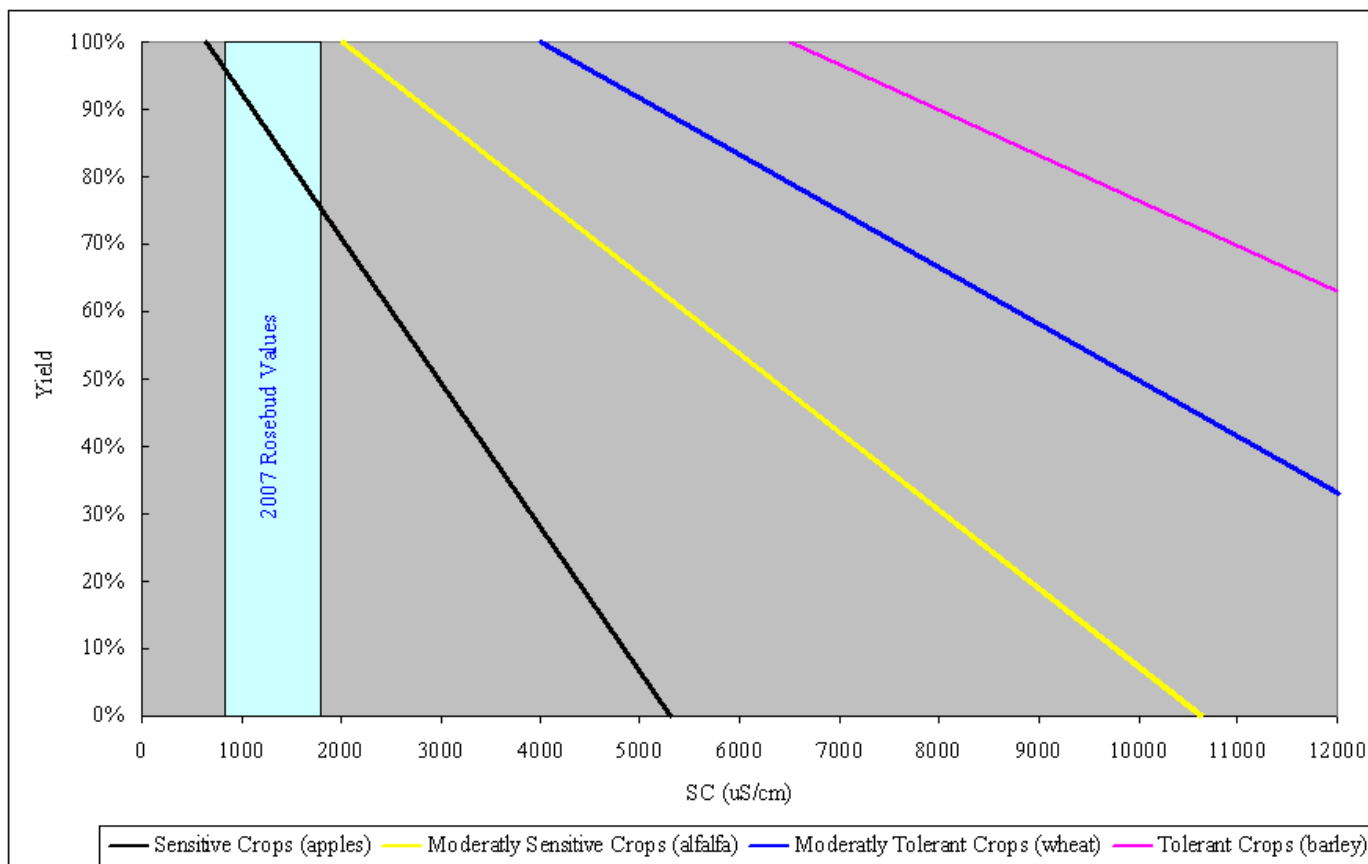


Figure 1 shows the range of SC values measured in water-quality samples collected periodically from Rosebud Creek during water year 2007 compared to yield vs. salinity curves for representative crops (Ayers and Westcott, 1985). Note that yield comparisons are made to that which would be attained using low salinity irrigation water, and assumes that all other factors are equal. Values ranged from 816 to 1790 uS/cm.

Figure 2: Comparison of Infiltration Criteria and 2007 SC and SAR Values Measured in the Rosebud Creek Watershed

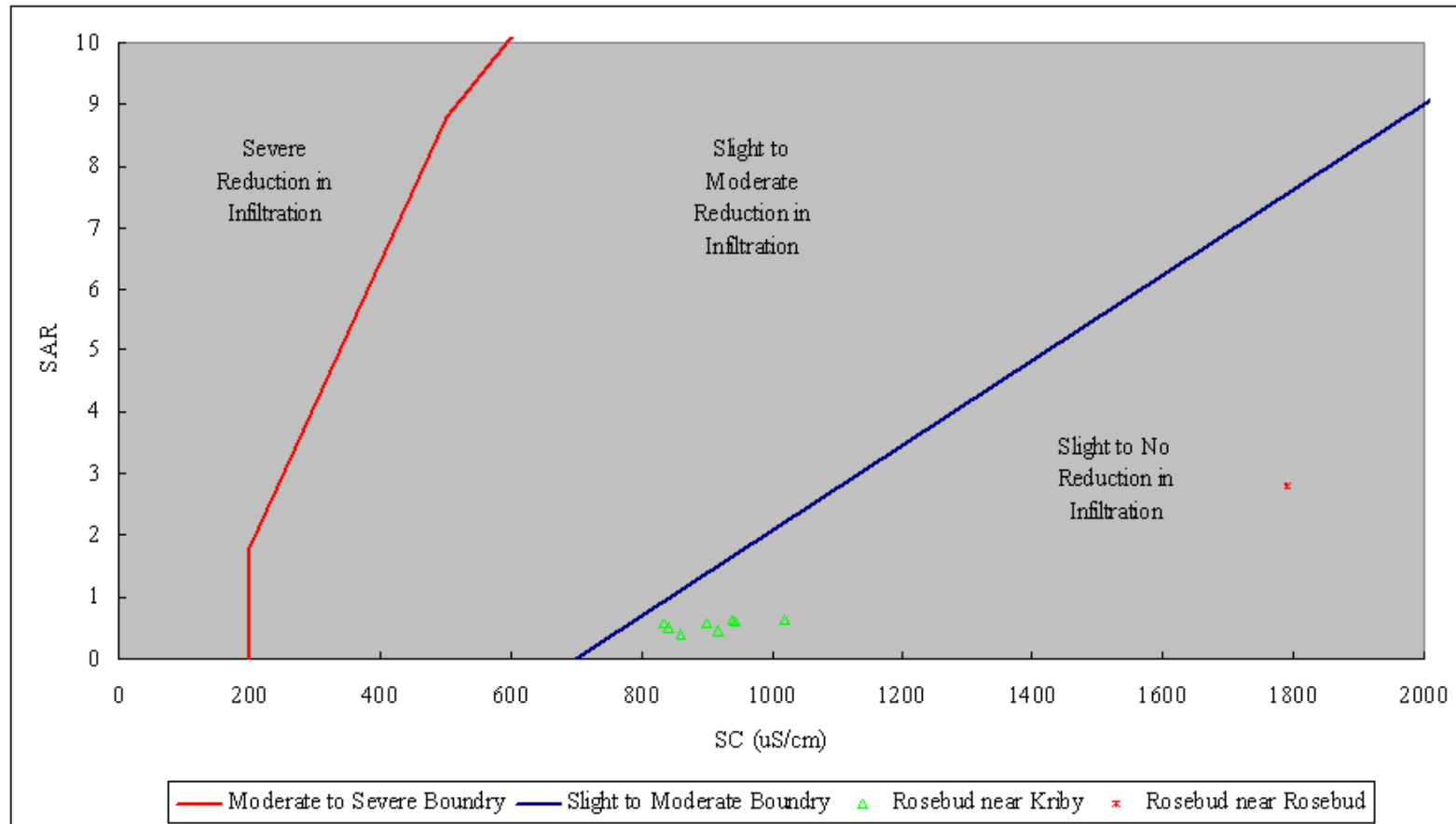


Figure 2 shows water quality data from samples collected in water year 2007 in the Rosebud Creek Watershed compared to the infiltration criteria developed by Hanson et al. (1999). All values fall within the Slight to No reduction in infiltration field.

Figure 3: Rosebud Creek near Kirby

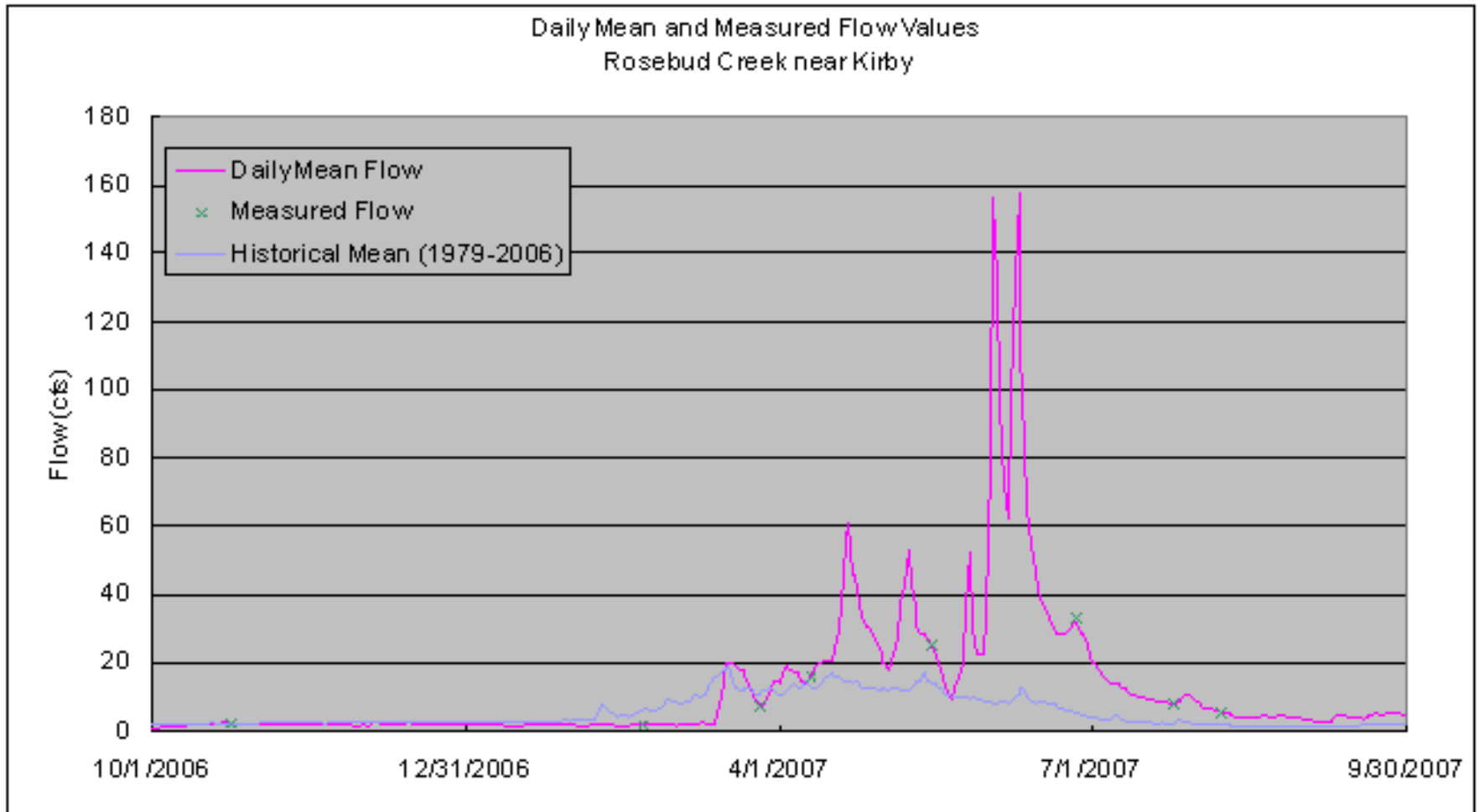


Figure 3 shows mean daily and field measurements of flow in a time series plot for water year 2007 for Rosebud Creek near Kirby. Mean daily flow values ranged from 0.7 to 157 cfs. The historical mean daily flow values are also shown to place the data in context.

Figure 4: Rosebud Creek near Kirby

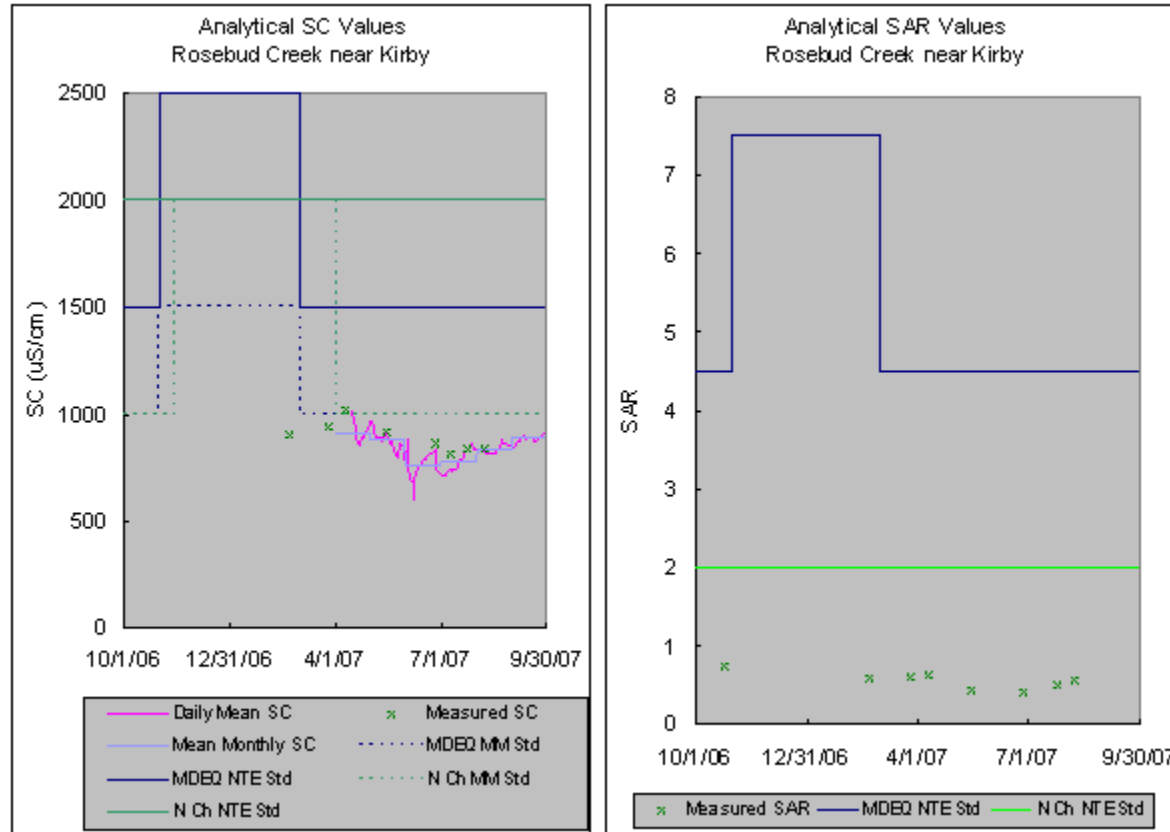


Figure 4 shows analytical and daily mean SC values (A) and analytical SAR values (B) in time series plots for water year 2007 for Rosebud Creek near Kirby. Mean Monthly SC values are also shown. SC values ranged from 605 $\mu\text{S}/\text{cm}$ to 1020 $\mu\text{S}/\text{cm}$. Analytical SAR values ranged from 0.4 to 0.7. These values are compared to the NTE standards developed by the MDEQ and the Northern Cheyenne Tribe. All values were below the applicable standards.

Figure 5: Rosebud Creek near Kirby

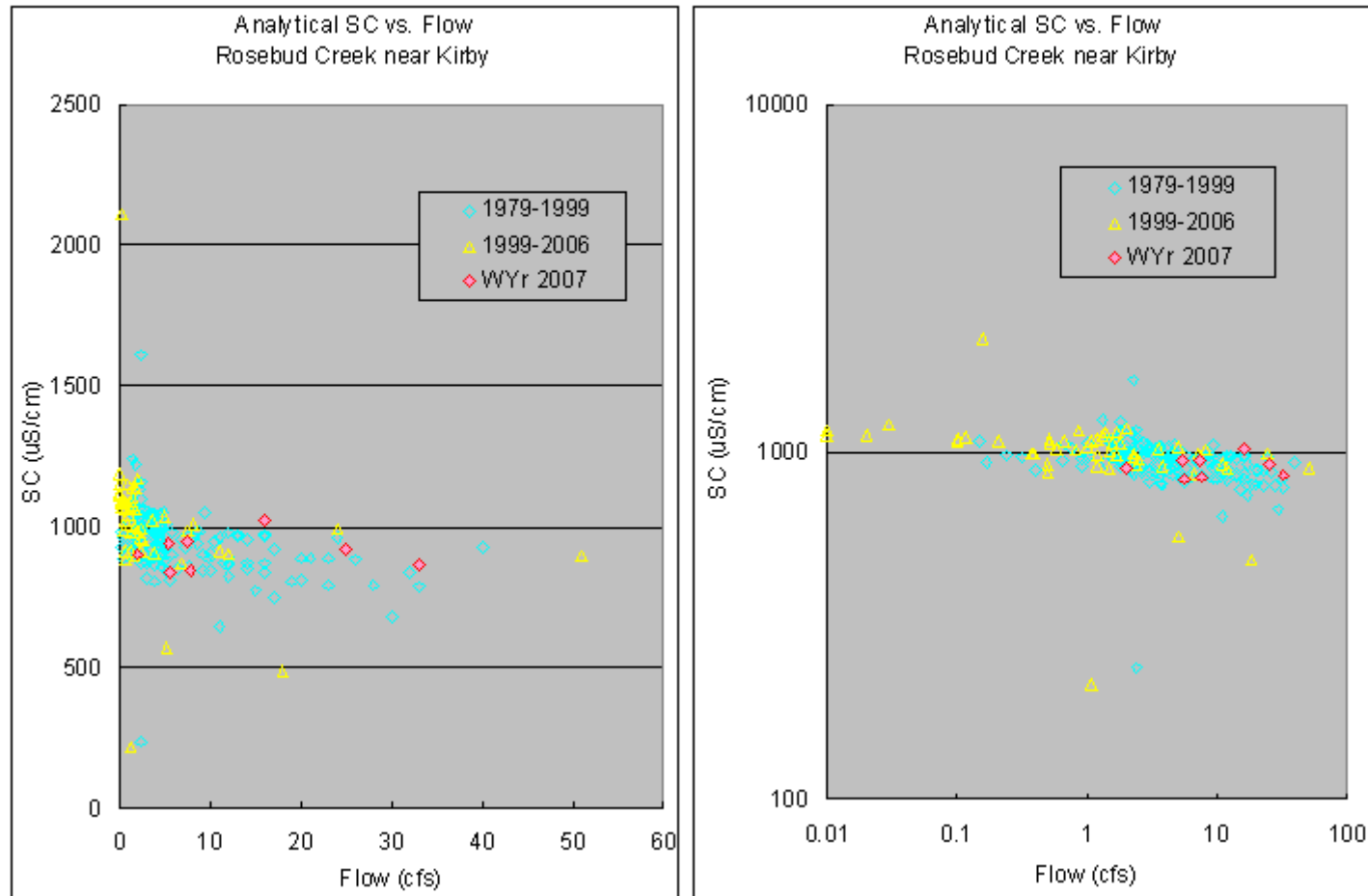


Figure 5 shows analytical SC vs. Flow data for water year 2007 for Rosebud Creek near Kirby. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 6: Rosebud Creek near Kirby

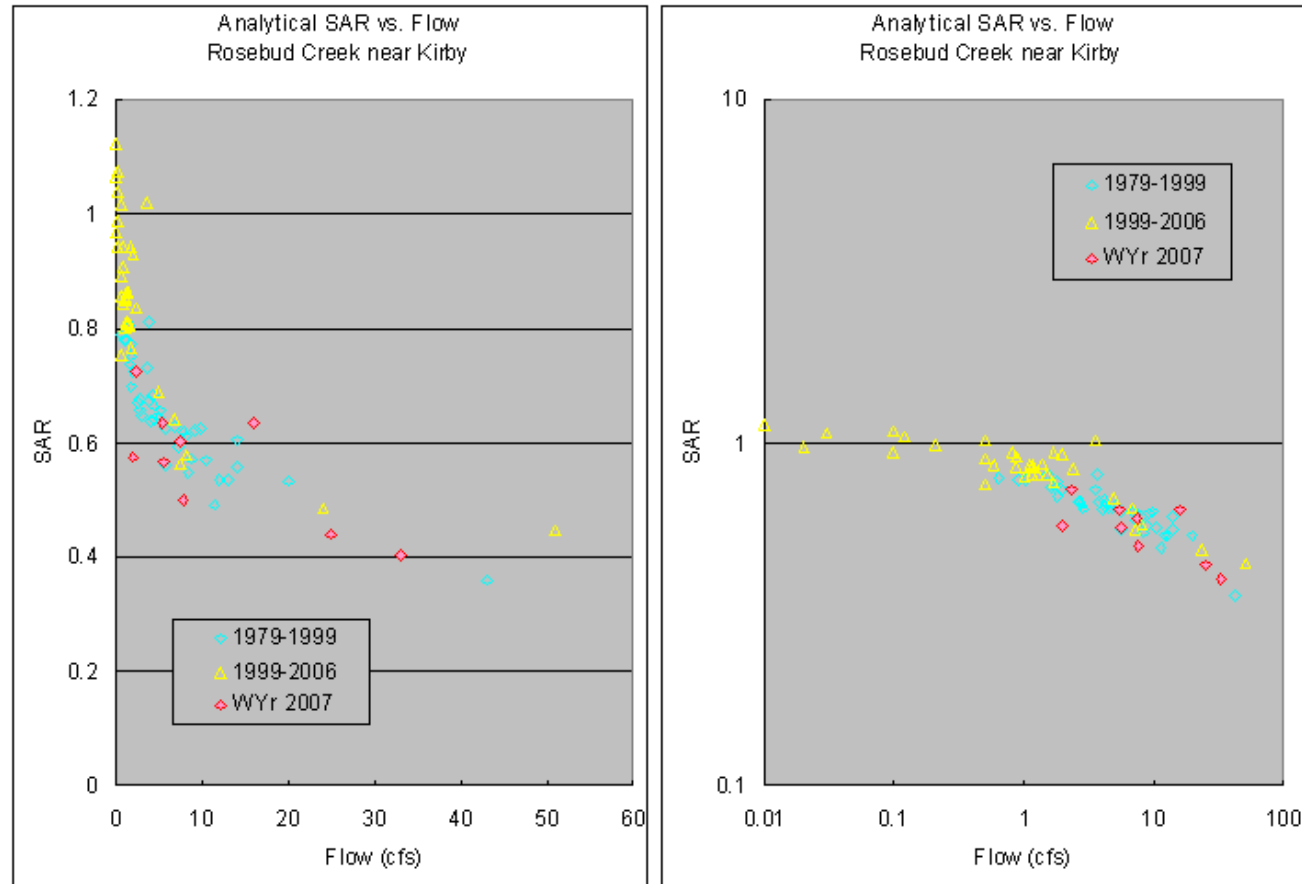


Figure 6 shows analytical SAR vs. Flow data for water year 2007 for Rosebud Creek near Kirby. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 7: Rosebud Creek near Kirby

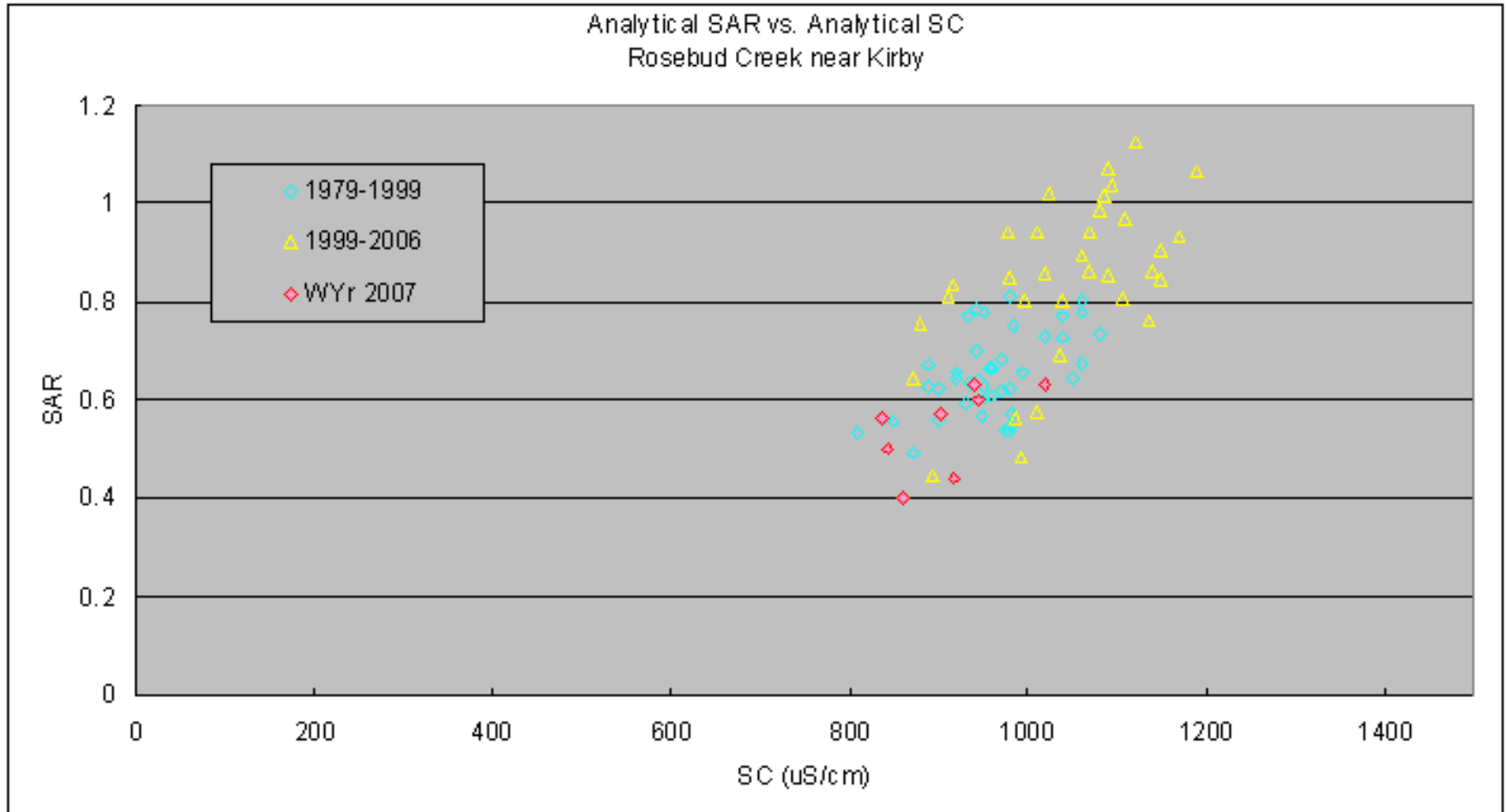


Figure 7 shows analytical SAR vs. analytical SC data for water year 2007 for Rosebud Creek near Kirby. Historical SAR vs. SC data are also shown to place the data in context.

Figure 8: Rosebud Creek near Rosebud

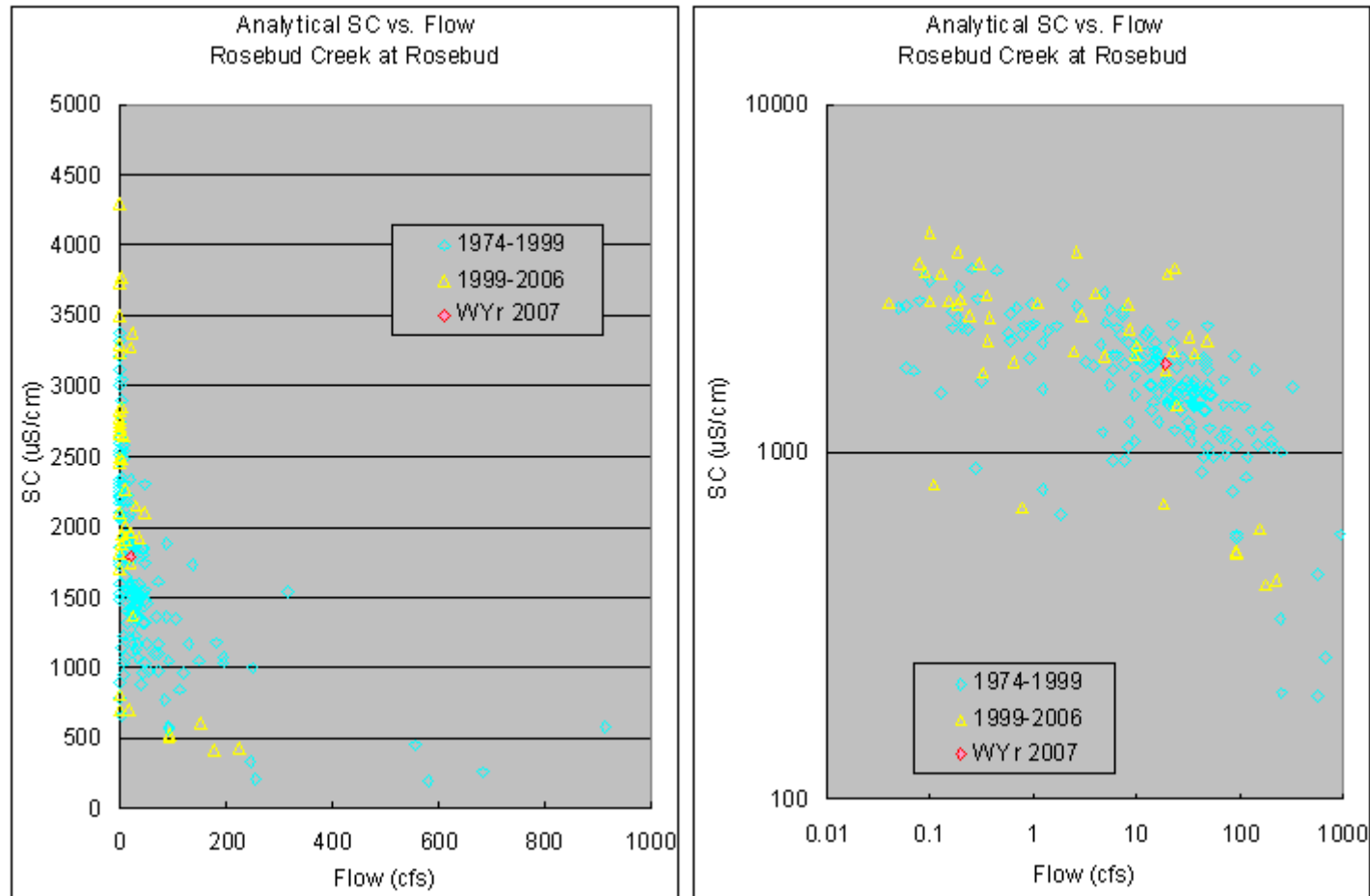


Figure 8 shows analytical SC vs. Flow data for water year 2007 for Rosebud Creek near Rosebud. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 9: Rosebud Creek near Rosebud

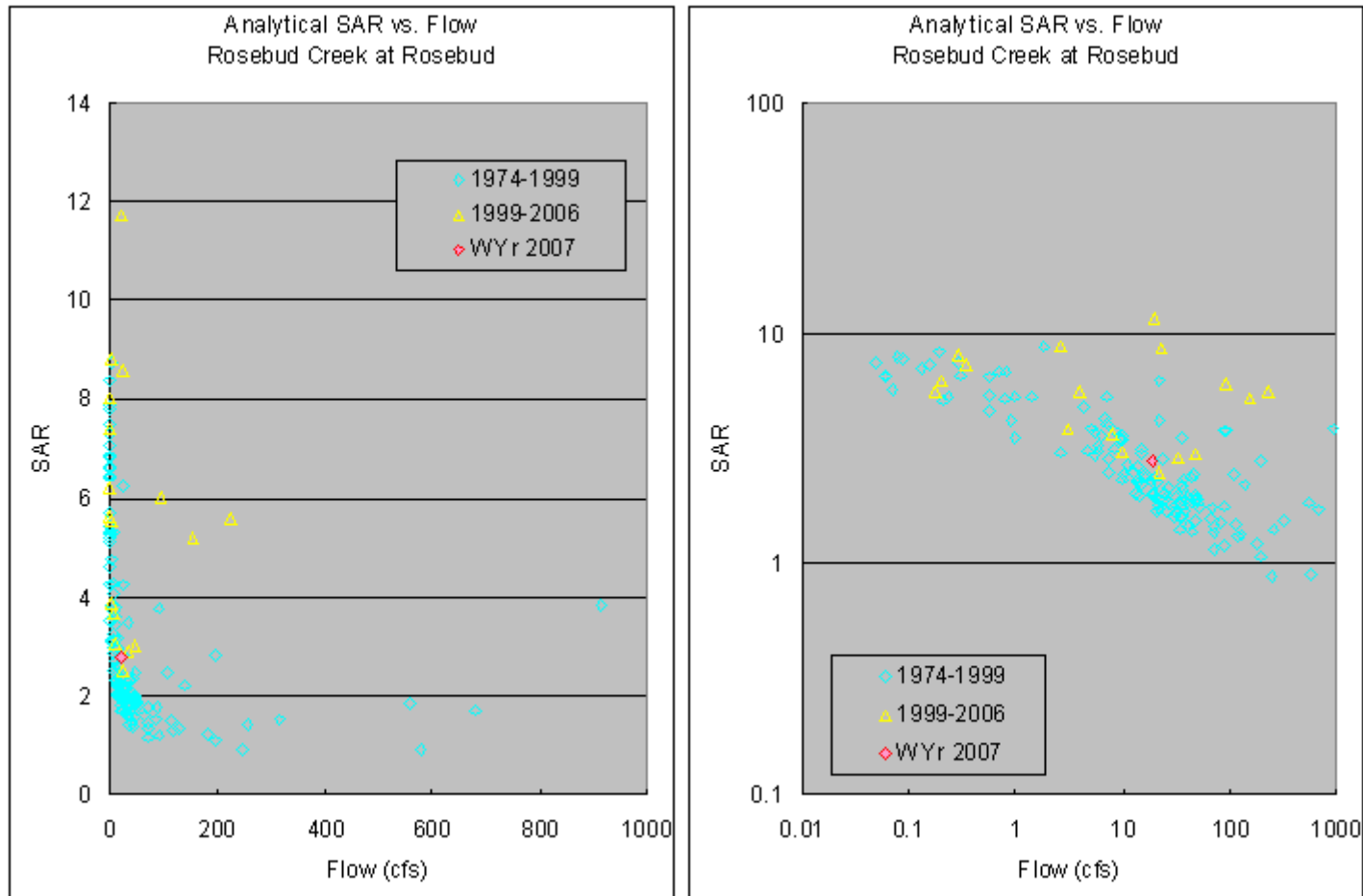


Figure 9 shows analytical SAR vs. Flow data for water year 2007 for Rosebud Creek near Rosebud. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 10: Rosebud Creek near Rosebud

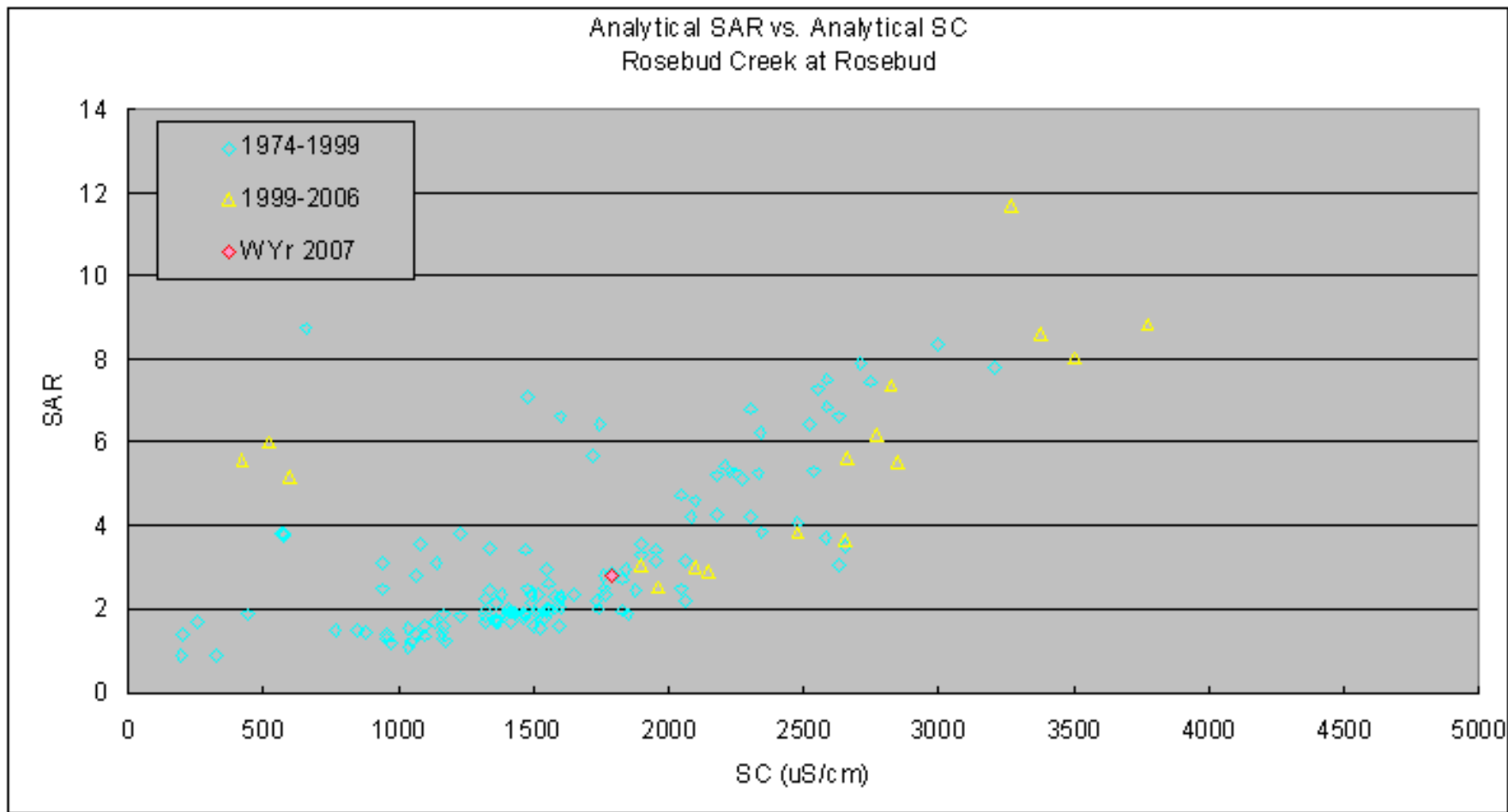


Figure 10 shows analytical SAR vs. analytical SC data for water year 2007 for Rosebud Creek near Rosebud. Historical SAR vs. SC data are also shown to place the data in context.